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Opinion Document

98/2018 September 27, 2018

*Debalina Ghoshal**

Hypersonic Weapons: The new age weapon system

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Abstract:

Speed has become a crucial factor in ensuring both conventional as well as nuclear deterrence. Today with sophistication in missile defence systems, ballistic and cruise missiles need to be high speed weapon systems to be able to evade enemy missile defence systems and deliver warheads at the target accurately. High speed weapon systems can render missile defence system useless and it is usually difficult to intercept supersonic and hypersonic cruise missile technology.

Missile defence systems have only increased the arms race with states developing more sophisticated weapon systems that can render the missile defence system null and void. While ballistic missile defence (BMD) has become a deterrent against ballistic missiles, states have also started to develop hypersonic technology vehicles that can be mounted atop ballistic missiles to negate the deterrent capability of the BMDs.

Hypersonic weapons can become strategically destabilising if states start to develop the same. This is more so true in case the weapon system is fitted with nuclear warheads as is the case with China and Russia.

While the ideal solution is to ban the weapon systems, such a solution is only utopian in nature. Hence, states should not nuclearize their hypersonic weapon systems if they are to maintain strategic stability.

Keywords:

Hypersonic speed, nuclear deterrence, missile defence, counter measure, time sensitive.

NOTA:** Las ideas contenidas en los ***Documentos de Opinión son de responsabilidad de sus autores, sin que reflejen, necesariamente, el pensamiento del IEEE o del Ministerio de Defensa.

Introduction

Hypersonic vehicles are those vehicles which travel faster than the speed of sound that is, Mach 5 or more but less than Mach 25. Any vehicle traveling below this speed is a subsonic or supersonic weapon. In fact, NASA has already come out with another term called “high-hypersonic” vehicles, that is those vehicles within the speed of Mach 10 to Mach 25, while simple hypersonic vehicles ranging up to Mach101. The author has classified hypersonic vehicles in this paper under two categories:

- Hypersonic cruise missiles: Hypersonic cruise missiles are those cruise missiles which could travel at five times the speed of sound.

- Hypersonic boost glide vehicles atop ballistic missiles: These are systems which execute a pull-up manoeuvre in order to avoid ballistic missile defence system and these weapon systems are mounted atop ballistic missiles but do not follow a ballistic trajectory and travel at speeds five times the speed of sound.

There are many reasons why hypersonic weapon systems have gained the attention of strategic and military planners. They are as follows:

- Time sensitive targets: Work on hypersonic weapons has started way back in the 1950s. It is only after 1998 when US Tomahawk missile failed to reach a target on time in Afghanistan where Osama Bin Laden that hypersonic vehicles gained prominence for the United States. High speed weapon systems then became the need of the hour to reach time sensitive targets. States today are developing weapon systems which are highly mobile and re-locatable, for example, road and rail mobile missiles and submarines on patrol. Hence, to destroy such targets, it was required to develop such weapons that would need to fly at an amazing speed to be able to destroy such targets before they are relocated completely. For example, the hypersonic weapon systems designed by the US, Russia and China are developed for “precise targeting and rapid delivery of weapons”

- For destroying hard and deeply buried targets: Defeating hard and deeply buried targets is defined as the “capability to deny sanctuary to adversaries by developing end-to-end capabilities for detection, characterisation, target planning, defeat, and combat assessment directed at deeply buried, tunnelled, and other hard-to-defeat, high value

targets."[1] It "employs a full range of measures to destroy, disrupt, or deny hard and deeply buried target facilities as well as mission-critical elements within the networks that support or are supported by such facilities." Hard and deeply buried targets are most difficult to destroy and would require swift actions since such weapon systems could make the task of defeating hard and deeply buried targets a little easier. Moreover, some of these targets may be protected by sophisticated defensive systems. Hypersonic systems thus, are most appropriate for hard and deeply buried targets.

States today are developing sophisticated missile defence technology which has to the development of counter-measures on the missile systems against the missile defence systems to mollify these defence systems and enhance their strike capability. Interception of a hypersonic cruise missile and also a hypersonic glide vehicle on a ballistic missile could be a Herculean task. In fact for supersonic and hypersonic cruise missiles, it is less of the stealth factor which enables the missile to evade missile defence system, but the speed at which the missile flies that makes a missile defence system difficult to intercept the missile.

Technological features that make hypersonic systems crucial for strategic deterrence

A unique feature of hypersonic cruise missiles is that the hypersonic vehicle will work on 'air breathing technology' rather than on rocket technology. This makes them lighter and easier to carry heavier warheads for greater ranges. The "maturation of high speed air-breathing propulsion technology is [also] a critical step in the development of combined cycle engines that will enable more cost effective, on-demand access to space for future systems."[2]

Scramjet engines used in these hypersonic vehicles use air breathing technology whereby the oxygen which is needed by the engine for combustion purpose is taken from the air passing through the vehicle instead of taking it from an on-board oxygen tank. Scramjet engines could use either hydrogen fuel or hydro carbon fuels. Hydrogen fuel is

[1] Hard and Deeply Buried Target Defeat, *Department of Defense deputy Under Secretary Of Defense,* <http://www2.gwu.edu/~nsarchiv/NSAEBB/NSAEBB372/docs/Document11.pdf>

[2] "HyTech (Hypersonic Technology], *Global Security,* <http://www.globalsecurity.org/military/systems/munitions/hytech.htm>

easily flammable resulting in small amount of energy needed for igniting and making it burn faster hence, generating huge thrust. However, their low density makes it inappropriate to be used for scramjet engines. On the other hand, hydro-carbon fuel is denser than hydrogen fuel, thereby enabling missiles to fly longer distances. [3] Moreover, hydrocarbon is easier to store than hydrogen fuel and hence easier and less hazardous to work with and also logistically more supportable. The United States' X-51A Wave Rider hypersonic weapon system is reported to be using hydrocarbon fuel. [4] Thus, these systems are less hazardous to be deployed and can easily reach time sensitive targets and destroy them too.

Holding up missiles at those speeds of Mach 5 or 6 involves enormous technical challenges. Developing hypersonic vehicles is not an easy task and states like the United States and Russia have been trying their luck for a while now. Moreover, according to a report in the Economist, scramjets "cannot begin flight on their own power" and hence, "because they need to be moving quickly to compress air for combustion, scramjets must first be accelerated by piggybacking on a jet plane or rocket"[5] which is a difficult task.

In addition, dual mode ramjet (DMRJ) is also under development that would work as ramjet engine until the missile has reached a designated speed and altitude and then the scramjet engine would start to work. Hypersonic weapons would travel along the edge of space and accelerate between Mach 5-Mach 10.[6]

Even though the pressure loss inside a scramjet is higher than that compared to ramjet, yet ramjet is not apt for hypersonic speeds since this low pressure does not compensate for the loss of thermal energy. The boosters in the hypersonic cruise missiles could either be tandem boosters or side-mounted boosters. Tandem boosters are suitable for cruise missiles fitted with naval ship platforms "to meet the constraints of the vertical and canister

[3] See Debalina Ghoshal, "The U.S. X-51A Wave Rider: U.S. Gears Up For Prompt Global Strike," *In Focus,* February 6, 2014, <http://capsindia.org/files/documents/CAPS_Infocus_DG_2.pdf>

[4] Daryl Mayer, "X-51 Wave Rider achieves history in final flight," *Wright-Patterson Air Force Base,* March 5, 2013, <http://www.wpafb.af.mil/news/story.asp?id=123346970>

[5] For more on this see "Speed is the new stealth," *The Economist,* June 1, 2013, <http://www.economist.com/news/technology-quarterly/21578522-hypersonic-weapons-building-vehicles-fly-five-times-speed-sound>

[6] "Hypersonic Weapons Basic," *Missile Defence Advocacy,* May 30, 2018, <http://missiledefenseadvocacy.org/missile-threat-and-proliferation/missile-basics/hypersonic-missiles/>

launch systems" while side-mounted boosters are fitted with air-launched platforms. [7] However, getting a scramjet engine into a missile is difficult since one needed "sophisticated guidance tools, sensors and navigation equipments to keep it in the air and to its target."[8]

In a Hypersonic Glide Vehicle, since the glide is unpowered, the Initial Guide Conditions of the HGVs which include the initial height, speed, path angle and azimuth would be crucial for the flight since this would influence the "maneuverability and the gliding trajectory constraints."[9] The initial height should not be too high or too low. If the initial height is too high then there could be a chance of wide oscillations of the glide trajectory and also "a severe peak value of the constraints such as heat flux and dynamic pressure will occur."[10] If the height is too low then the vehicle "will rapidly drop in the dense atmosphere, thus dramatically increasing drag and significantly reducing range."[11] Similarly cross range can be increased by causing a large deviation of the azimuth from the east. Wave rider configuration provides good aerodynamic performance. This performance could be reduced if wave riders are blunted. However, this limitation in blunted wave rider can be corrected by lift to drag ratio which should be enough for glide trajectory.[12] Except the nose region, the heat transfer of the HGV is not very serious for which carbon-carbon can be used for fabrication.[13]

In a study it has been predicted that there could be chances of hypersonic vehicles triggering any electro-optical event like red sprites, blue jet and elves because it has been understood that meteors and re-entering space-crafts leave ionised trails which could

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[7] Michael E. White and Walter R. Price, "Affordable Hypersonic Missiles for Long-Range Precision Strike," *John Hopkins APL Technical Digest,* Volume 20, Number 3, 1999.

[8] Robert Beckhusen, "Russia Preps Mach7 Missiles-With India's Help," *Wired,* June 28, 2012, <http://www.wired.com/2012/06/hypersonic/>

[9] Yan Xiaodong, Lyu Shi, Tang Shuo, "Analysis of Optimal Glide Conditions for Hypersonic Glide Vehicles," *Chinese Journal of Aeronautics,* March 2, 2014, <http://ac.els-cdn.com/S1000936114000284/1-s2.0-S1000936114000284-main.pdf?_tid=5b1825d4-e2fc-11e3-b7a1-00000aab0f27&acdnat=1400906104_58e86cb2a618219065dba622d8daf2ca>

[10] Ibid.

[11] Ibid.

[12] Liu Jian-xia, Hou Zhing-xi, Chen Xiao-qing, "Numerical Study of Hypersonic Glide Vehicle based on Blunted Waverider," *World Academy of Science, Engineering and Technology,* Volume 5, July 22, 2011, <http://waset.org/publications/5684/numerical-study-of-hypersonic-glide-vehicle-based-on-blunted-waverider>

[13] Ibid.

trigger such discharge. As of now NASA has been clear about the fact that flying over thunderstorms or into such electro optical events might not be dangerous or hazardous for the hypersonic vehicles and also the probability of doing so is low. However, if it is realised in future that flying over thunderstorms could be dangerous, then such vehicles would have to avoid flying over thunderstorms or even into electro optical events.[14]

Moreover, hypersonic glide vehicles could invite complications in aerodynamics, in dissipation of heat so that excess heat does not damage the re-entry vehicle, affect Global Positioning System since the high 'g' forces experienced by gliding re-entry vehicles when it "pulls up" out of the ballistic phase of flight and then into the gliding phase and also plasma generated through atmospheric heating can interfere with GPS reception.[15]

Strategic Implications

There are two ways of countering a new weapon system. One is to keep pace with the arms race initiated by the new weapon systems by developing similar systems in order to strengthen deterrence, whether conventional or nuclear. This strategy is called deterrence by punishment. The other strategy that could be adopted is deterrence by denial, that is, rather than developing offensive hypersonic weapons, states could choose to develop missile defence systems in order to counter such threats from adversaries. Hypersonic weapon systems will start a new hypersonic arms race. What makes matters worse is as can be seen that Russia and China are developing nuclear capable hypersonic weapon systems. Nuclear capable hypersonic missiles could increase chances of pre-emption by adversaries that could fear a decapitating strike on its counter-force targets. Therefore, for instance, while the threat of US using nuclear capable of hypersonic systems may not be existing, the threat of a pre-emptive nuclear strike by the US with the help of any other nuclear weapon system in case the threat is severe cannot be ruled out.

Hypersonic arms race is detrimental to strategic stability of not only a region but also global order especially if the weapon system is nuclear capable. Such weapons are

[14] Tim Garner, "International Conference on Space Planes and Hypersonic Systems and Technologies," *Johnson Space Centre,* October 2002, <http://www.srh.noaa.gov/topics/attach/pdf/ssd02-31.pdf>

[15] James M. Acton, "Silver Bullet?: Asking the Right Questions About Prompt Global Strike," *Carnegie Endowment for International Peace,* 2013.

capable of rapid delivery of warheads that would provide minimal reaction time. At the same time, manoeuvrability and in-flight updates provide the HGVs the scope to attack different targets thereby, allowing them to keep larger areas at threat. They can hold both fast mobbing objects like aircraft carriers as well as high value targets at threat including a state's leadership as well as command and control. [16] Such a threat could result in threatened states allocating command and control of weapon to lower authorities that could risk the escalation of accidental and irrational launch of weapons. This especially holds true in case of weapons like tactical nuclear weapons (TNWs.)

The Missile Technology Control Regime (MTCR) does hold some restrictions on hypersonic technology, but countries like China are not a party to the MTCR. Moreover, "because hypersonic missiles require little or no payload to constitute a threat, they do not conform to the payload requirements in the regime's definition of a missile that is subject to its tighter restrictions."[17] MTCR demands that states confirm to payload capacity of 500kgs and hence, since weapons like HTVs may not carry any payload hence, they do not need to abide by the 500kg restriction put forward by the MTCR. In fact according to a RAND Report, "the MTCR aims to inhibit only the proliferation of missiles capable of delivering nuclear, chemical, or biological payloads, and hypersonic missiles need to deliver a mass destruction warhead in order to effective." [18]

Hypersonic arms race

Russia

Until 2012, Russia was lagging behind the United States in the field of hypersonics and thus there was a realisation of boosting the development of such systems. In fact in 2012, Russians have also raised concerns over the US hypersonic vehicles like the X-51,

[16] Richard H. Speier, George Nacouzi, Carrie A. Lee, Richard M. Moore, "Hypersonic Missile Nonproliferation: Hindering the speed of a new class of weapons," *RAND Corporation,* 2017, <https://www.rand.org/content/dam/rand/pubs/research_reports/RR2100/RR2137/RAND_RR2137.pdf>

[17] Richard H. Speier, "Hypersonic missiles: A New Proliferation Challenge," *The RAND Blog,* March 29, 2018, <https://www.rand.org/blog/2018/03/hypersonic-missiles-a-new-proliferation-challenge.html>

[18] N. 16

Falcon, HiFire and HyFly which could pose "perspective threat"[19] to the Russian hypersonic development process. However, in 2013, there were also reports that the RS-26 Rubezh is equipped with hypersonic manoeuvring nuclear units which could enable the missile to evade missile defence systems.[20] There were also reports earlier that the Topol-M carried hypersonic warheads. By 2014, the United States had already raised concerns that Moscow could develop long range hypersonic cruise missiles which could violate the INF treaty obligations. [21] The Obama administration also alleges that the Russian R-500 Iskander-K is a hypersonic cruise missile, upgraded version of the Iskander series of short range missiles.[22]

Russia is also collaborating with India to develop the BrahMos hypersonic cruise missiles, which would be air-launched, ground-launched and sea-launched keeping intact the weight and dimension similar to that of the BrahMos supersonic ones. [23] Reports in 2013 claimed that Russia is likely to hand over India the hypersonic versions of the anti-ship missile systems however; delay in the finished product is being caused for the "lack of material that can protect its guidance system from overheating and subsequent failure."[24] For the development of hypersonic technology there is also a plan by Russia to set up an aerospace "super-holding" involving several companies to develop hypersonic technologies. [25]

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[19] Tula, "Russian 'Super-Holding' to Build Hypersonic Missile- Rogozin," *Ria Novosti,* September 19, 2012, <http://en.ria.ru/military_news/20120919/176062184.html>

[20] Dmitriy Litovkin, "Russia's hypersonic trump card edges closer to reality," *Russia and India Report,* October 23, 2013, <http://in.rbth.com/economics/2013/10/23/russias_hypersonic_trump_card_edges_closer_to_reality_30325.html>

[21] Fred Weir, "Shades of the cold war? US eyes Russia on arms-treaty violations," *The Christian Science Monitor,* January 31, 2014, <http://www.csmonitor.com/World/Security-Watch/2014/0131/Shades-of-the-cold-war-US-eyes-Russia-on-arms-treaty-violations>

[22] Ibid.

[23] BrahMos Aerospace to Develop First Prototype of BrahMos Missile by 2017, *Defence Now,* <http://www.defencenow.com/news/752/brahmos-aerospace-to-develop-first-prototype-of-brahmos-2-hypersonic-missile-by-2017.html>

[24] Dmitriy Litovkin, "Russia's hypersonic trump card edges closer to reality," *Russia and India Report,* October 23, 2013, <http://in.rbth.com/economics/2013/10/23/russias_hypersonic_trump_card_edges_closer_to_reality_30325.html>

[25] n.19

Besides, Russia is working on hypersonic glide vehicle (HGV) called the Yu-71 under the secret project 4204. [26] This HGV will be capable of travelling at 20 Mach speed. In 2016, the HGV was mounted atop the RS-18 ICBM and the glide technology would enable the HGV to not only manoeuvre but also would extend the range of ballistic missile. The warhead would be capable of carrying nuclear warheads. The HGV is a component of Russia's 4202 Project that aims to develop weapon systems that could evade US missile defence system. [27] RS-28 Sarmat missiles on the other hand are reported to employ the new Avangard HGV on it and would carry a single thermonuclear warhead according to reports[28].

Russia also developed the Kinzhal hypersonic weapon that is also capable of launching nuclear warheads. The missile is also referred to as the Kh-47M2 that has been test fired from the Russian MiG-31BM.[29] Just like the other hypersonic weapons, this air-to-surface missile too has manoeuvrable features. The missile would have a range of 2000kms giving the aircraft a better stand-off capability, thereby reducing the scope of the aircraft being destroyed by possible enemy air defences. This would provide the aircraft deep strike capability and also keep the missiles invincible against enemy air defences. [30]

Moreover, nuclear weapons in any case do not require much precision as opposed to conventional warheads, and hence, Russia is not even concentrating on the accuracy of

[26] "Russia will put advanced mach 20 hypersonic boost and glide missile into service in 2019," *Next Big Future,* March 21, 2018,< https://www.nextbigfuture.com/2018/03/russia-will-put-advanced-mach-20-hypersonic-boost-and-glide-missile-into-service-in-2019.html>

[27] Jeffrey Scott Shapiro, "Russia launching new hypersonic missile to carry nuclear warheads," *The Washington Times,* June 26, 2015, <https://www.washingtontimes.com/news/2015/jun/26/russia-launching-new-hypersonic-missile-carry-nucl/>

[28] Dave Majumdar, "We now know how Russia's New Avangard Hypersonic Boost Glide Weapon will launch," *National Interest,* March 20, 2018, <http://nationalinterest.org/blog/the-buzz/we-now-know-how-russias-new-avangard-hypersonic-boost-glide-25003>

[2929] Tom Demerly, "Russia Test Fires New KH-47M2 Kinzhal Hypersonic Missile," *The Aviationist,* March 12, 2018, <https://theaviationist.com/2018/03/12/russia-test-fires-new-kh-47m2-kinzhal-hypersonic-missile/>

[30] Debalina Ghoshal, "Russia's new Kinzhal missile and what it means for the US,?" *Daily Sabah,* April 29, 2018, https://www.dailysabah.com/op-ed/2018/04/30/russias-new-kinzhal-missile-and-what-it-means-for-the-us

the hypersonic weapon system as opposed to the United States that is laying stress on the accuracy of the hypersonic weapon system.[31]

United States

There is no denying in the fact that for the United States, two of the major reasons for developing such systems is to be able to strike time critical targets successfully and to be able to counter adversary's 'anti-access area denial' strategies. Though for the United States work on hypersonic systems started in the 1960s itself, hypersonic development in the United States suffered due to the concentration of the military on other traditional arms development like bombers and missiles under "replacement strategy" due to technical difficulties in developing these hypersonic systems.[32] In 1995, it was decided by NASA Langley and Dryden to flight test the Hyper-X vehicle with Pegasus solid propellant booster mounted under the wing of the B-52B "with the Hyper-X vehicle mounted atop the booster through a load carrying adaptor."[33]

The United States is particularly working on hypersonic cruise missiles in order to develop a successful Prompt Global Strategy for which concentration is being given to "overall missile kinematic performance, launch platform compatibility, C4ISR, targeting requirements, accurate guidance and navigation, survivability and payload lethality."[34] The Common Aero Vehicles is also one such attempt by the US to develop hypersonic glide vehicles.

In 2004, NASA's X-43A experimental space plane achieved a speed of Mach 10 breaking its own record of flying at speed of 7Machs. Also NASA, the Air Force Research Laboratory and Australia's Defence Science and Technology Organisation are working on Hypersonic International Flight Research Experimentation Program in order to explore

[31] Matt Stroud, "Inside the Race of Hypersonic Weapons," *The Verge,* March 6, 2018, <https://www.theverge.com/2018/3/6/17081590/hypersonic-missiles-long-range-arms-race-putin-speech>

[32] Richard P. Hallion, "Whither Hypersonics? A Foreword to the 1998 Edition," in ed., *The Hypersonic Revolution: Case Studies in the History of Hypersonic Technology,* Volume I, 1998, <http://www.afhso.af.mil/shared/media/document/AFD-100927-033.pdf>

[33] Ibid.

[34] Michael E. White and Walter R. Price, "Affordable Hypersonic Missiles for Long-Range Precision Strike," *John Hopkins APL Technical Digest,* Volume 20, Number 3, 1999.

"the fundamental technologies needed to achieve practical hypersonic flight."[35] In 2011, the US also flight tested its Advanced Hypersonic Weapon which would have a longer range.[36]

The United States is also working on a High Speed Strike Systems which are hypersonic missiles capable of being launched from bombers and fighter aircrafts. These missiles are reported to enable "responsive strike capability on time-critical, heavily defended targets achieves high survivability through altitude, speed and stealth." [37] These missiles are reportedly to be carried by the F-22 Raptor or an F-35Joint Strike Fighter in order to render "enemy's anti air-craft system defunct." They are reported to be efficient even in the most stringent environment. In fact, according to a Carnegie Report, the United States for their Conventional Prompt Global Strike capability is concentrating on advanced hypersonic weapons (an intercontinental glider), hypersonic technology vehicle (global glider), and submarine launched ballistic missiles (SLBMs) which could carry hypersonic gliders, and hypersonic cruise missiles.[38]

The United States has also made considerable progress in wave-rider technology like the X-51 wave riders. A wave-rider is a "hypersonic configuration which is designed to have shock wave attached to the leading edge of the vehicle, thus preventing the high pressure behind the shock wave to leak from the lower surface to the upper surface."[39] This weapons system is expected to have the potential of improving the ability of a weapon to "enter enemy territory and shorten time necessary for U.S. troops to respond to targets." [40] The X-51 wave rider was a technology breakthrough since before this, the

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[35] "HIFiRe scramjet research flight will advance hypersonic technology," *Science Daily,* May 12, 2012, <http://www.sciencedaily.com/releases/2012/05/120512100649.htm>

[36] "U.S. tests hypersonic weapon," *Ria Novosti,* November 18, 2011, <http://en.ria.ru/military_news/20111118/168813926.html>

[37] "High Speed Strike Weapon," *Lockheed Martin,* <http://www.lockheedmartin.com/us/products/high-speed-strike-weapon--hssw--.html>

[38] James M. Acton, "Silver Bullet?: Asking the Right Questions About Prompt Global Strike," *Carnegie Endowment for International Peace,* 2013.

[39] Liu Jian-xia, Hou Zhing-xi, Chen Xiao-qing, "Numerical Study of Hypersonic Glide Vehicle based on Blunted Waverider," *World Academy of Science, Engineering and Technology,* Volume 5, July 22, 2011, <http://waset.org/publications/5684/numerical-study-of-hypersonic-glide-vehicle-based-on-blunted-waverider>

[40] Brendan Mcgarry, "Air Force Sees Hypersonic Weapons in 2025," *Defensetech,* May 13, 2013, <http://defensetech.org/2013/05/13/video-air-force-sees-hypersonic-weapons-in-2025/>

United States had flown hydrogen fuelled hypersonic aircrafts while this weapon system was being flown with the help of hydro-carbon jet fuel known as the JP-7.[41]

Effort is also being made to make the hypersonic cruise vehicle reusable and hence, such weapon system would not be the fire and forget type of weapon. However, reports suggest that developing re-usable vehicles is difficult than developing expendable ones since re-usable ones would need to "carry additional mass for systems such as landing gear, wings, and thermal tiles." [42] Sometimes the re-usable vehicles may also need to "first stage reverse course and execute a powered return to base." [43]

In April 2018, the Lockheed Martin Space Systems won the contract of indefinite delivery and indefinite quantity award up to worth $928million to develop hypersonic cruise missile. According to Michael Griffin, undersecretary of defence for research and engineering, developing hypersonic weapons is the "highest technical priority" for the US military.[44] This is probably because according to Admiral Harry Harris, head of Pacific Command, China's hypersonic weapons "outpaces" that of the United States. [45]

China

Hypersonic vehicle is expected to be a "major step forward in China's secretive strategic nuclear and conventional military and missile programs."[46] In early 2014, China too tested a hypersonic glide vehicle called the Wu-14 which could be mounted atop a ballistic missile. This could enable the ballistic missile to evade a ballistic missile defence. According to John Stillion, the HTV developed by Beijing which is believed to be mounted

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[41] Ibid.

[42] Ronald P. Menich, "First west, then east," *The Space Review,* January 6, 2014, <http://www.thespacereview.com/article/2427/1>

[43] Ibid.

[44] Garett Reim, "Lack of funds causes USAF to skip hypersonic cruise missile competition," *Flight Global,* June 4, 2018, <https://www.flightglobal.com/news/articles/lack-of-funds-causes-usaf-to-skip-hypersonic-cruise-449192/>

[45] "Pentagon looks to counter rivals' hypersonic missile," *The Japan Times,* February 17, 2018, <https://www.japantimes.co.jp/news/2018/02/17/world/pentagon-looks-counter-rivals-hypersonic-missiles/#.WxjKDjSFPIU>

[46] Bill Gertz, "Hypersonic arms race: China tests high-speed missile to beat U.S. defenses," *The Washington Times,* January 13, 2014, <http://www.washingtontimes.com/news/2014/jan/13/hypersonic-arms-race-china-tests-high-speed-missil/?page=all>

atop ballistic missiles like the DF-21D could provide greater maneuverability to the missiles and greater ability to the missile to evade ballistic missile defence system than the existing maneuverable cone-shaped re-entry vehicle. This vehicle carrying warheads whether nuclear or conventional would be difficult to detect and intercept since the trajectory of these vehicles do not reach outer space unlike that in ICBM trajectory. [47] It is also expected to increase the range of ballistic missiles, especially useful since Chinese missile systems suffer range limitations due to MIRVs fitted on them or depressed trajectory or lofted trajectory. If mounted atop anti-ship ballistic missiles like the DF-21D, it would increase the range of the ASBMs and put US aircraft carriers at threat, thereby affecting their rebalancing strategy in the Asia Pacific.[48] Hypersonic anti-ship missiles are being developed not just by Russia and the United States, the two Cold War rivals, but such complicated weapons systems are also being ventured upon by Asian states like India and China which could put US naval supremacy in doldrums.

South Asia

India is also developing hypersonic vehicles. India is working on Hypersonic Technology Demonstrator Vehicle for which Defence Research and Development Laboratory is working on scramjet engines and is reported to use hydrogen fuel.[49] Such vehicles can be used for two purposes: one to launch satellites at low cost and the other to develop long range cruise missiles for the future.[50] The BrahMos hypersonic cruise missile as being developed by BrahMos Aerospace India Limited in collaboration with Russia is expected to be a version of Sudarshan Chakra, a deadly weapon of Lord Vishnu described in Hindu mythology. BrahMos missile would be similar to Sudarshan Chakra in the sense that it would travel very fast and also be recallable and hence, can be used again.

[47] Mike Wall, "China Launches Hypersonic Missile Tests, Downplays Fears," *Space.com,* January 16, 2014, <http://www.space.com/24317-china-hypersonic-missile-weapons-test.html>

[48] Debalina Ghoshal, "China's hypersonic vehicle: Yet another 'Assassin Mace' Weapon?", *IIT Chennai, China Centre,* February 24, 2014, <http://www.csc.iitm.ac.in/?q=node/478>

[49] "Missile Designer," *The Hindu,* May 10, 2005, <http://www.hindu.com/thehindu/thscrip/print.pl?file=20130208300205300.htm&date=fl3002/&prd=fline&>

[50] Ibid.

According to reports, Pakistan too has deployed Chinese made 'carrier killer' hypersonic missiles. These missiles would be long range air launched missiles and probably would be dropped by the JF-17s. The missile is called the CM-400 AKG and is already in service with Pakistan's Air Force.[51] The missile is reported to have a range of 180-200kms and can be used against fixed or slow moving targets.[52] The kinetic impact of the missile would be more than enough to destroy aircraft-carriers. The weapon is a solid rocket powered weapon that can either be fitted with a penetrator or blast/fragmentation warhead. [53]

Defending against hypersonic weapon systems

A perfect integration of aerospace defence systems comprising of air and missile defence systems, missile early warning attack and space controls could facilitate hypersonic cruise missile interception. Directed energy weapons could be answer to counter hypersonic glide vehicles given their ability to engage targets at the speed of light, but these DEWs are also restricted to line of sight engagements and would also need to overcome "atmospheric attenuation". The US Missile Defence Agency is actively working on these limitations. [54] Laser weapons are being developed in order to enable boost phase interception- the ideal phase to intercept a missile.

With hypersonic glide vehicles becoming a reality, there has been a concern if the directed energy weapons on interceptors can be effective against such systems due to low warning time and greater manoeuvrability.

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[51] "China Develops CM-400AKG Pakistan's Hypersonic Carrier Killer Missile For JF-17," *Asian Defence, News,* 2012, <http://www.asian-defence.net/2012/11/China-Developed-CM-400AKG-Pakistans-Hypersonic-Carrier-Killer-Missile-For-JF-17.html>

[52] "China Develops CM-400AKG Pakistan's Hypersonic Carrier Killer Missile For JF-17," *Asian Defence News,* 2012, <http://www.asian-defence.net/2012/11/China-Developed-CM-400AKG-Pakistans-Hypersonic-Carrier-Killer-Missile-For-JF-17.html>

[53] "China Develops CM-400AKG Pakistan's Hypersonic Carrier Killer for JF-17," *Asian Defence News,* <http://www.asian-defence.net/2012/11/China-Developed-CM-400AKG-Pakistans-Hypersonic-Carrier-Killer-Missile-For-JF-17.html>

[54] Collin Meisel, "Stopping the Unstoppable: How will the U.S. Defeat Missiles of the Future?", *Real Clear Defense,* April 4, 2017, <https://www.realcleardefense.com/articles/2017/04/04/stopping_the_unstoppable_how_will_the_us_defeat_missiles_of_the_future_111095.html>

The glide is flat and hence enables the missile to evade missile defence system. It also extends the range of the missile. This means boost phase interception could become a tough call. Jamming could be an option to defeat hypersonic missiles. However, as regards to the HGVs, when the warheads enter the atmosphere, their speed is slower and the altitude is also low and hence, can become easy targets for the low-tier interceptors like rail guns.[55] All said, the US Strategic Command General however, clarified that at least the United States for the moment does not have any defence against hypersonic threats. [56]

However, the best option to defeat hypersonic cruise missiles would be to destroy them while they are still attached with the aircrafts or submarines or ships or Transporter Erector Launchers (TELs). This can be done by destroying the medium that is destroying the aircrafts, submarines, ships and TELS. Hence, to defeat hypersonic cruise missile, adopting an offensive strategy can ensure good defence. This means that could become difficult to have active defences against hypersonic cruise missiles.

Developing a cruise missile defence against hypersonic cruise missiles should be cost effective which means that the cost of developing missile defence system as means of defence by denial. According to reports, the Terminal High Altitude Area Defence (THAAD) system, especially the THAAD-ER uses two-stage interceptor with higher velocity that may be capable of destroying hypersonic missiles. [57] Having said this, it must be noted that gliders anyway are difficult to track with the existing radar technology of the United States. However, the infra-red seeker in THAAD can lock on to infra-red heat signature.

The best defence against these missiles is to tighten non-proliferation measures in order to prevent the spread of such technologies to developing states. It must be noted that in the future, states like Iran and North Korea could be interested in such technologies too. This could further ameliorate the threat to the United States since then the threat would

[55] Daniel Katz, "Introducing the Ballistic Missile Defense Ship," *Aviation Week,* April 11, 2014, <http://aviationweek.com/blog/introducing-ballistic-missile-defense-ship>

[56] Frank Gaffney Junior, "We Can Defeat Hypersonic Missile Threats," *Centre for Security Policy,* March 29, 2018, <https://www.centerforsecuritypolicy.org/2018/03/29/we-can-defeat-hypersonic-missile-threats/>

[57] Bill Gertz, "Pentagon Seeks Weapons To Counter Hypersonic Missiles," *Washington Free Beacon,* August 16, 2016, <http://freebeacon.com/national-security/pentagon-seeks-weapons-counter-hypersonic-missiles/>

not only be from sophisticated ballistic missiles nut also from almost invincible cruise missiles. Such missiles could be used to carry nuclear warheads and other weapons of mass destruction.

Conclusion

Hypersonic systems are not only expected to enable development of more efficient cruise missiles, but also "develop new generation launch-vehicles, super-fast suborbital aircraft" and also "manned space planes capable of reaching orbit after a horizontal take-off from a runway." [58] But at the same time, while hypersonic weapon systems can be a game-changer against states possessing missile defence systems, they are of little value against those countries that do not have missile defence systems or even if they have, the defence is not credible. This is because such a state is already vulnerable to missile threats with or without hypersonic speeds. In addition, despite the efforts of Russia, China and the United States in the hypersonic field, it would take another ten to fifteen years for states to reach perfect sophistication in the technology.

In the near future, hypersonic arms race would become more rampant and states would look towards developing such systems in order to develop sophisticated missile systems for evading missile defence. States would need proper policy, strategy and objectives to defeat ballistic, hypersonic and cruise missile threat that would also need to explain the posturing, capability and force structure along with long term goals.

While a complete ban on such systems is the only solution viable for preventing proliferation challenges in future, it is obvious that states like Russia, China, and United States and also India would not accept such a ban as these states have heavily invested in these technologies. The world will only have to live with these sophisticated weapon systems, and look for means to strengthen strategic deterrence. In the near future, West Asian countries could also seek to acquire such weapon systems from Russia and China even if the United States refuses to provide such weapon systems to them.

[58] "Russia jump-starts hypersonic flight research," *Russian Space Web,* January 18, 2013, <http://www.russianspaceweb.com/gla.html>

There is little doubt in the fact that hypersonic vehicles including boost glide vehicles would provide significant military advantage. However, given the cost of developing such weapon systems, it is crucial to estimate the benefits that military planners would gain with such systems. If the benefits are no game changer, then trade-off would be difficult to cope with.

*Debalina Ghoshal**
Independent consultant